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Subject:	FW: Answers to OFIC/forest industry questions
Date:	Wednesday, June 18, 2014 4:37:09 PM
Attachments:	Responses to Concerns Raised by OFIC_June19th2014_figures.pptx DEQ-ODFW Notes_Responses to PCW Concerns Raised by OFIC_Jun19th2014_draft.docx Responses to PCW Concerns Raised by OFIC_Jun19th2014_All.docx

FYI. The "DEQ-ODFW Notes…" document is not for public distribution, but rather back pocket notes for Dave Jepsen and I.

Josh

From: SEEDS Joshua
Sent: Wednesday, June 18, 2014 4:35 PM
To: JEPSEN David B; FOSTER Eugene P; BOROK Aron; MICHIE Ryan
Cc: SEEDS Joshua
Subject: Answers to OFIC/forest industry questions

Hi all. I have updated the documents put together for the May 14th with new information about biology (thanks, Dave!), thermal fluxes and loads (thanks, Ryan!), and so on. Disturbance info has been updated to address riparian specifically in addition to the general information.

Thanks,

Josh

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Notes for Responses to Questions/Concerns Raised by OFIC
Re: Protecting Cold Water Criterion of the Temperature Standard

Oregon Departments of Environmental Quality and Fish & Wildlife

Date: 6/19/2014

Questions/Assertions from Forest Industry Representatives:

1. Paired watershed studies alleged to show no correlation between temperature and salmon, steelhead, and bull trout (SSBT) population metrics.
    a. What was the temperature response in these studies?
        i. Hinkle Type-N stream-adjacent harvest (Kibler *et al* 2013):
            1. Flow increases on streams post-harvest (76-161%).
            2. Shaded due to logging slash.
            3. One stream (Fenton) had insignificant shade change (-4%), change in maximum temperature was -1.6°C.
            4. Three streams had shade decreases (-22 to -29%), change in maximum temperatures were +0.6, +0.7, +1.1°C.
            5. Pooled results for all Type-N streams indicate no significant change in maximum, mean, or minimum temperatures: No overall change.
            6. No significant temperature changes at watershed outlet (South Fork Hinkle Creek).
        ii. Hinkle Type-F stream-adjacent harvest (Arne Skaugset, *personal communication*, compiled by Terry Frueh(ODF)):
            1. Average changes of +0.4°C for stream temperature, -9.5% canopy cover on average.
            2. Temperature probes align with tributaries, not necessarily harvest units.
        iii. Alsea stream-adjacent harvest (Jeff Light, *personal communication*, compiled by Terry Frueh(ODF) & Paired Watershed Research Symposium (April 2013):
            1. Small Type-N stream: Stream temperature change was +0.5°C.
            2. Small Type-F (bottom of harvest unit): Stream temperature change was +0.7°C, -14% for shade.
            3. Small Type-F (bottom of unharvested reach downstream of harvest unit): Stream temperature change was +0.3°C.
        iv. Comparing Hinkle and Alsea Type-F stream-adjacent harvest with RipStream results (Compiled by Terry Frueh(ODF)):

Table 1. Summary data on changes in temperature, shade, and basal area for two WRC studies (Alsea and Hinkle) and RipStream.

Study (n=# of sites)	ΔT (ºF) (n=# of sites)	ΔShade (%)(n=# of sites)	Pre-harvest total basal area (ft.²/ac.) within 100 feet of stream (n=# of sites)	Post-harvest basal area (ft.²/ac.) within 100 feet of stream (n=# of sites)
Alsea (n=1)	+1.3 (+0.7°C)	-14	NA	37[2]
Hinkle	(n=3): +0.7[1] (+0.4°C)	(n=3): -9.5	Mainstem (n=4): 186	Mainstem (n=4): 149
			Type F tributary(n=2): 172	Type F tributary(n=2): 127
RipStream (n=18)	+1.3 (+0.7°C)	-7	Small Type F (n=4): 187	Small Type F (n=4): 87[2]
			Medium Type F (n=14): 207[2]	Medium Type F (n=14): 128

[1]Change in temperature was measured at junctions with tributaries, which does not necessarily correspond with the downstream end of a harvest unit.
[2]Total basal area excluding that of alders.

b. Did studies examine SSBT? What was general response? **[ODFW]**
   i. Hinkle did not look at SSBT, did look at resident cutthroat trout.
      1. Cutthroat: Small increases in size & total biomass (continuation of pre-harvest upward trend?).
   ii. Alsea did look at coho salmon & resident cutthroat.
      1. Coho: No response.
      2. Cutthroat: Adult biomass increased, juvenile size decreased, no response otherwise.

c. Are resident cutthroat a good proxy for SSBT? **[ODFW]**
   i. While sea-run cutthroat have similar temperature requirements as other salmonids, resident cutthroat do not have to undergo smoltification in order to survive ocean conditions. As a result, increased feeding in areas with higher temperature would not affect timing of smoltification as it does with anadromous fish (Trotter 1989).
   ii. Resident cutthroat trout have shorter lives & mature more quickly than sea-run cutthroat trout (Trotter 1989).
   iii. Irrespective of potentially different physiological needs, research indicates that cutthroat populations are found in lower abundance in secondary forest than in clear cuts or old growth (Murphy *et al* 1981).
   iv. Temperature increase of 1°C in upper extent of cutthroat habitat has been shown to not cause changes in cutthroat abundance or body condition when

understory vegetation & stream habitat was not altered by logging (DeGroot *et al* 2007).

d. What is the appropriate inference for the studies, with regard to fish?
    i. Reach level acute effects on fish population are the appropriate inference.
    ii. Short-term (ecologically speaking), local examination of population dynamics, primarily for cutthroat trout.
        1. Shows no acute damage to local cutthroat populations.
        2. Limited inference for SSBT.
        3. Limited inference for long-term local population effects.
        4. Limited inference for watershed, sub-basin, and basin level effects.
    iii. Therefore, cannot draw conclusions about SSBT at Evolutionarily Significant Unit (ESU) or sub-population level.

e. Is this assertion relevant to the purpose & construction of the temperature standard?
    i. The purpose of the standard is maintenance and restoration of natural thermal regimes. Diversity in habitat conditions enhances ecosystem resiliency.
    ii. The Protecting Cold Water (PCW) & Human Use Allowance (HUA) criteria restrict anthropogenic warming in waterbodies below & above the biologically-based numeric criteria (BBNC), respectively, & implement the purpose of the standard. The BBNC are primarily thresholds for identifying impaired waterbodies. The standard protects cold-water aquatic communities, including amphibians, macroinvertebrates, & native fish of all types.
        1. Welsh *et al* (2001) found that amphibians & coho salmon were most common (preferred) in streams with weekly average & weekly maximum temperatures below the BBNC.
            a. With MWMT <16.3 or MWAT<14.5, coho were always present.
    iii. The BBNC are set at the high end of the optimal temperature range for salmonids (US EPA 2001).
    iv. Meeting the standard preserves the capacity of waterbodies to assimilate natural fluctuations in temperature due to year-to-year climate variations & to better maintain cold-water communities in a warming climate.
    v. While the standard can be used to restrict activities that cause immediate, acute harm at the reach level, it is a regime standard designed to protect entire aquatic ecosystems from both acute & chronic anthropogenic impacts.
    vi. Therefore, the assertion ignores the larger purpose of the standard to focus on short-term, reach-level effects.

2. Alleged that there is no scientific support for the conclusion that small increases in water temperature (in reaches below the numeric criteria) are harmful to SSBT in either a localized or landscape sense, short- or long-term.
    a. We agree, to an extent, depending on how “small” is defined. That is one purpose of the 0.3°C limit on anthropogenic warming. We have a high degree of confidence that warming at or below this limit will not affect fish or cold-water communities (DEQ 2003: Temperature TAC Summary Report).

i. Effects are on a continuum; the further we increase temperature from the natural thermal potential, the higher risk there will be for the fish.
ii. The BBNC are set at the high end of the optimal temperature range for salmonids (US EPA 2001).
iii. Consideration of accuracy of measurement is another reason for the 0.3°C limit. The State's policy on stream temperature is that natural thermal regimes should be protected and, where necessary, restored.
iv. Under the Clean Water Act, existing high quality waters cannot be degraded unless it is necessary to accommodate important economical or social development in the area in which the waters are located, and BMPs are achieved for nonpoint sources.

b. Heating of headwaters reduces the extent of downstream waters at optimal growth & optimal physiological temperatures & increase the extent of downstream waters at high-risk & lethal temperatures for rearing & migration.
c. Intermittent upper reaches can provide coho habitat in residual pools during low flows & during winter high flows (Wigington *et al* 2006).
    i. Smolts overwintering in intermittent streams are larger than those overwintering in perennial streams.
d. Fish are poikilotherms, so metabolic rates & processes are regulated by the temperature of their environment (US EPA 2001).
    i. Faster metabolism results in faster growth up to the optimum growth temperature provided adequate food is available.
    ii. Faster metabolism results in energy stress when adequate food is *not* available (see McCullough 1999).
    iii. Ability to avoid predators adapted to warmer water decreases with increasing temperature. Swimming is less efficient at higher temperatures (US EPA 2001).
    iv. Invasive species often do better in warmer temperatures, tipping the competitive balance (see McCullough 1999).
    v. Changes in disease resistance with increasing temperature (McCullough 1999, US EPA 2001):
        1. Constant temperatures below 12-13°C often reduce or eliminate both infection and mortality;
        2. Temperatures above 15-16°C are often associated with high rates of infection and notable mortality;
        3. Temperatures above 18-20°C are often associated with serious rates of infection & catastrophic outbreaks of many fish diseases.
    vi. Increases in temperature flux (range) have been connected with increases in morbidity & mortality (see McCullough 1999).
        1. RipStream results show an increase in stream temperature fluxes post-harvest; this is a common effect of riparian vegetation removal.

vii. If adult fish are exposed to temperatures above 13-15.6°C during the final part of upstream migration or during holding there is a detrimental effect on the size, number, and/or fertility of eggs (US EPA 2001).

viii. Changes in behaviors can result from increases in temperature below the numeric criteria (US EPA 2001).

1. Warmer temperatures may lead to earlier out migration in salmon & reduced ocean survival (Holtby 1988).
2. Smoltification is very temperature sensitive, even to temperatures lower than the BBNC (McCullough 1999, US EPA 2001).

e. The NTR is dynamic and variable, and promotes **biological diversity** among fish populations and other native aquatic organisms.

i. The NTR includes the magnitude, frequency, duration, timing, and rate of temperature change (Olden and Naiman 2010). Landscape conversion and climate change alters the mean and *the variance* of these temperature components (Steel et al. 2012).

ii. The timing of fish life history attributes (adult migration, spawning, fry emergence, smolt migration) that are partially mediated by the NTR. This phenology reflects adaptation of salmonid populations to a "temporally-ordered" sequence of variability (Vannote and Sweeney 1980) to which fish populations have presumably adapted.

iii. Homing to natal streams promotes reproductive isolation in Pacific salmonids, and natural selective forces (including those imposed by NTR) operate on heritable phenotypic traits, resulting in distinct, *locally adapted* populations (Hillborn et al. 2003).

iv. Thus, dampening the natural thermal variability and the temporal sequence of the NTR reduces intraspecific diversity by reducing opportunities for local adaptation and genetic variation among populations or phenotypic variation within populations (Watters et al. 2003), and therefore, salmonid species diversity in Oregon.

v. Since diversity also confers stability in salmon population dynamics (production cycles), a diverse temperature regime also promotes population and meta-population (ESU) resilience. In addition, diversity in spawn timing among Pacific salmon and steelhead confers a stable food resource for other biota (Ruff et al. 2011).

f. Heat accumulation and other homogenizing effects may alter thermal heterogeneity well before changes to "average" main channel temperatures are detected (Poole and Berman 2001).

g. Thermal diversity promotes aquatic **biological productivity.**

i. If fish use temporal thermal diversity (migrating or foraging during cooler nighttime temperatures) or spatial thermal diversity (using cold-water refugia during mid-day) then impacts to the "pattern" of temperature could be as significant as changes to the mean or maximum temperature (DEQ 2003).

ii. It is not well understood how changes in temporal or spatial patterns of thermal diversity impact fish population dynamics, however it can be assumed that population dynamics are more closely linked to the dynamic spatial and temporal variability (diversity) of water temperatures and flows than to the mean of water temperatures.

iii. Fish can detect and exploit thermal heterogeneity to avoid heat stress, and meet metabolic and reproductive requirements (Berman and Quinn 1991, Hodgson and Quinn 1991, Torgersen et al. 2012).

iv. Under non-stressful temperature conditions juvenile coho that exploited thermal heterogeneity grew at substantially faster rates than did individuals that assumed other behaviors (Armstrong et al. 2013). This supports an emerging hypothesis that fish exploit thermal heterogeneity not only to survive, but thrive.

v. Variation in thermal regimes directly influence:

  1. Metabolic rates, physiology and life-history traits of aquatic ectotherms (see Holtby et al. 1989 for salmonid example) and
  2. Rates of important ecological processes such as nutrient cycling and productivity.
  3. It also indirectly mediates biotic interactions (references in Olden and Naiman 2010).

vi. Within a watershed stream network with multiple salmonid species, those with colder thermal requirements such as ESA-listed bull trout are almost completely confined to “cold-water refuges” in higher elevation headwater streams that are spatially isolated. If these refuges become warmer, bull trout habitat availability will shrink, due to competitive disadvantage with other salmonid species in the drainage network.

vii. Thermal refuges below the species-specific BBNC buffer cool/cold water adapted species from predation by invasive warm water predators.

viii. In warm streams, thermal refuge patches provide opportunities for fish to thermoregulate (Ebersole et al. 2003). Having a spatially distributed network of reaches and segments with cooler temperatures allows a fish population to utilize a larger portion of a stream network, thereby reducing density dependent and density independent mortality.

h. Multiple stressors in the environment must be considered. By preventing or reducing temperature stress, we reduce the risks due to multiple stressors on fish populations (see Baird & Burton 2001, US EPA 2001).

  i. Temperature increases, even below the numeric criteria, reduce the resistance of coho salmon to damaging effects of suspended sediment (Servizi & Martens 1991).
  ii. Feeding & growth rates of native & nonnative fish which feed on juvenile salmon increase as temperature increases (EPA 2001).

        iii. Cyprinid fish (e.g. redside shiners) are competitively favored over salmonids at warmer temperatures (EPA 2001).

    i. Water quality (particularly summer stream temperature) was identified in the Oregon Coastal Coho Assessment & Oregon Coastal Coho Conservation Plan as the secondary bottleneck for most coastal coho ESUs.
    j. Stream complexity contributes to thermal diversity.
        i. Cold groundwater (~7°C) influx & hyporheic exchange/conduction can account for apparent cooling downstream of harvest units (Story *et al* 2003). Cooling only occurred in gaining reaches.
        ii. Rather than cooling streams, hyporheic flows have a buffered temperature range (higher lows, lower highs) & are phase shifted (lagged) relative to the surface flow (water entering the hyporheic zone during the cool part of the day will likely exist during the warm part of the day & vice versa; Arrigoni *et al* 2008).
        iii. Hyporheic exchange is increased by stream complexity (Woessner 2000 & Dent *et al* 2001, cited in Story *et al* 2003 & Torgersen *et al* 2012).
        iv. Hydraulic effects of large woody debris (slowing & deflection of streamflows) create alluvial channels where there would otherwise be bedrock channels, increasing hyporheic & subsurface flow with attendant effects on temperature regimes (Montgomery *et al* 1996).
        v. Stream complexity (e.g. deflection & pool formation from boulders & large wood) increases the size & extent of cold water refugia by slowing mixing of cold water seeps with the main waterbody (Bilby 1984, cited in Torgersen *et al* 2012).
    k. When there is uncertainty, DEQ must make conservative choices to ensure protection of the resource.
        i. Uncertainty due to dynamics of the system (stochasticity).
        ii. Uncertainty due to our incomplete understanding of the system.
        iii. Uncertainty due to using sample data to observe the system.

3. Alleged that increases in temperature (at levels seen in RipStream) will diminish to less than 0.3°C within 300m on average. What can we say about downstream effects (in detail)?
    a. Physics of heat gain/loss.
        i. During summer, efficiency of heat loss is much lower than that of heat gain via solar radiation.
            1. In open canopy streams, input of solar radiation typically composes about 50% – 90% of the total heat energy flux (Johnson 2004, Benyahya *et al* 2012) & is the primary driver of heat transfer related to stream temperature change (Figures 1 & 2).
        ii. Added flow (increased mass of water) dilutes heat, but most heat remains in the system (e.g. Hannah *et al* 2008).
            1. Harder to detect the effects of a *single* source as water moves farther downstream.

2. Temperature is a measure of average thermal energy content, but DEQ also tracks thermal energy loads & fluxes (kcal) in TMDLs & other water quality programs.

iii. On small streams, DEQ HeatSource modeling indicates long distances (1000 meters +) are required to lose heat energy via evaporation and longwave radiation.

1. The loss is slow because these fluxes are the primary processes for loss of heat, and they represent a small proportion of the total input from increased solar radiation (Figure 1).
2. Tributary & groundwater mixing are held constant; only effects of vegetation change are modeled.

iv. DEQ HeatSource modeling indicates long distances (1000 meters +) are required to lose thermal energy via evaporation & longwave radiation (when flow is increased by x% to account for harvest-related flow increases).

1. Surfleet & Skaugset (2013) found 45% increase in August flows with 13% of watershed harvested in 2005. When an additional 13% was harvested in 2009 (26% total), flows were 106% higher in the 1st year (2010) & 47% higher in the 2nd year (2011).
2. Jones & Post (2004) looked at small PNW catchments with 100% harvest:
   a. ~50-100% increase in summer (June-Mid September) low flows 1-5 yrs post-harvest
   b. ~0-60% increase in summer low flows 6-10 yrs post-harvest
   c. ~30-50% deficits in summer low flows 24-35 yrs post-harvest

v. HeatSource modeling on 2 RipStream sites (5556 & 7854):

1. Agrees well with field measured responses at the end of the harvest units;
2. Shows persistent temperature increases a kilometer or more from the end of harvest units (Figures 3 & 4);
3. Harvest of additional downstream unit on 5556 creates greater increase at confluence with Drift Creek (Figure 5).

b. Trask Study results?

i. Preliminary results shown in Trask presumably showed privately harvested Type-N streams did not have readily detectable effects at downstream probe.

ii. Small headwaters (small Type-N) streams often behave differently & have small flows compared to fish-bearing reaches.

1. There is a great deal of change in heat capacity between harvest reaches & downstream sites, due to greater flows.

iii. The format of data presented to the GNRO is difficult to understand—need more information to have an interpretation of this data.

1. For example, does not appear to be harvest-related temperature changes on Type-N streams in harvest units. If true, wouldn't expect changes at downstream sites.

iv. Between Type-N harvest units & downstream probe is a RipStream study site.

1. During pre-harvest (2006-2011) period of Trask Study, RipStream site was in post-harvest condition (harvested in 2005, post-harvest year 1 was 2006).
2. RipStream site had challenging-to-interpret temperature behavior. 2W (control) probe had post-harvest increases & there was not much harvest in the Riparian Management Area, so unable to see any effects at 3W (treatment) probe.
3. Does this site confound interpretation of downstream effects from headwaters harvests?

c. Cole & Newton (2013) showed that with uncut units interspersed with harvest units, stream reaches showed overall increases in temperature trends 2 or 5 years post-harvest for 3 of 4 study reaches.

d. If taking a non-conservative approach to the effects of a single harvest, then we must address actual landscape conditions & the effects of multiple harvests.

4. Alleged that 2% of landscape in "early years" of rotation. What is the typical range, and what can we say about that?

a. Two questions:

i. How are the "early years" of the rotation being defined? It appears this figure may be % harvested per year on an even-flow 50-year rotation.

1. An appropriate thermal recovery window is 7-15 years, given the literature on temperature/shade recovery (Johnson & Jones 2000; D'Souza *et al* 2011; Rex *et al* 2012; RipStream data, *unpublished*).
2. Ten years is a reasonable mid-range timespan (See studies above; also Sherri Johnson, *personal communication*).

ii. What spatial scale is being considered? How does ownership vary across space?

b. Answers:

i. 2% harvested per year on average for a 50 year rotation. Rotation length is more often 40 years, so 2.5% of the land harvested per year on average. For a 10 year temperature recovery timespan, 25% of industrial forestlands would be in thermal recovery.

ii. There is high variation in percent ownership of forestlands (federal, state, municipal, private nonindustrial, private industrial) by sub-basin and basin and in harvest patterns.

iii. The average percentage of private forestland (65.1% of total land area) in the MidCoast basin in the 10-yr thermal recovery period is 17% for the time period 1985-2009. The average for all land uses combined is 10%.

1. An additional 5% did not have tree cover before 1985 & has not grown trees subsequently.

2. Varies over time & space.
    a. In 2008, 39.9% of private forestland in the Middle Siletz River watershed was in thermal recovery.
    b. In 1996, 5.3% of private forestland in the Drift Creek watershed was in thermal recovery. [34.9% in 2008]
3. Disturbance is calculated in rolling 10-yr intervals based on change in Landsat land cover from 1985-2009 (Figure 6).
4. Disturbance includes both harvest & fire.
5. Consistent with digitized harvest units area in ODF Vantage database (Kyle Abraham, *personal communication*)

iv. Based on change in Landsat land cover from 1985-2009, the average percentage of private forestland riparian areas in the MidCoast basin (43.8% of total riparian area (within 100ft of streams)) in the 10-yr thermal recovery period is 14.1% for the time period 1994-2009.
1. The average for private industrial forestland is 15.6% (36.2% of total riparian area) & for private nonindustrial forestland is 10.2% (7.6% of total riparian area).
2. The percentage of recently**+**chronically disturbed riparian areas is 20.7% for private forestlands during the same time period (20.4% & 21.8% for industrial & nonindustrial, respectively).
3. The average recent disturbance for riparian areas of all land uses collectively is 8.7%. The average chronic disturbance for riparian areas of all land uses collectively is 14.0%.
4. Varies over time & space.
    a. In 2008, 36.7% of private forestland riparian area in the Middle Siletz River watershed was in thermal recovery (maximum). The minimum of 14.1% occurred in 1994 (Figures 7 & 8).
    b. In 1996, 0.2% of private forestland riparian area in the Drift Creek watershed was in thermal recovery (minimum). The maximum of 25.8% occurred in 2008 (Figures 9 & 10).
    c. In 1999, 9.7% of private forestland riparian area in the Lake Creek watershed was in thermal recovery (minimum). The maximum of 34.5% occurred in 2008 (Figures 11 & 12).

v. In ODF's landslide study, (Robison *et al* 1999) 17% of study areas were in age class 0-9.

c. Prior to Euro-American settlement, fires created a heterogeneous (patchy) landscape with variable fire severity &varying intervals between fires.
    i. Fire return intervals in western Oregon range from 100-400 years. Shorter intervals typically are associated with less severity (Morrison & Swanson 1990).
    ii. Agee (1990) estimates that historically an average 0.24% and 0.67% of cedar/spruce/hemlock and Douglas-fir forests, respectively, burned annually.

iii. Cedar/spruce/hemlock average per 10 years=2.4%; Douglas-fir average per 10 years=6.7%.

d. Wimberly (2002) estimates that a median of 17% of Oregon's coastal province would be in early successional condition (<30 years since fire).
   i. These fires are not all stand replacement but vary in severity.
   ii. Using 10 years as above, Wimberly's estimate gives 5.67% of forestlands historically in thermal recovery.
   iii. Swanson *et al* (2011) document the differences between natural early succession and clearcut harvest.

e. High-severity fires leave more wood & live vegetation than clearcut harvest (see Reeves *et al* 2006). Fire return for high severity fires is typically 200 years (Wimberly 2002), compared to harvest rotation of 40 years.

f. Periodic large scale disturbances create a mosaic of riparian & aquatic habitats (Bisson *et al* 2003). Pulses of sediment & large wood are delivered by post-fire erosion, in contrast to chronic inputs.
   i. Emphasize the importance of conserving & restoring processes, not merely creating a structure or a condition.
   ii. Managing for & like a natural disturbance.

g. Fire is less common in riparian areas (higher moisture content & humidity). They often have higher fuel loads (higher productivity) & in prolonged drought become more fire-prone. Riparian fires tend to be very patchy, primarily burning fine fuels. Some studies (e.g. Tollefson *et al* 2004, Olson & Agee 2005) have found no difference between upland & riparian fire frequency, particularly when riparian vegetation is similar to upland vegetation. Streams higher up in watersheds are more likely to burn along with upland forests. (Upper riparian forests: more fire disturbance; lower riparian forests: more flood disturbance.) Conditions retard fuel drying & decrease severity. Harvesting increases fuel loads & opens up canopy, allowing faster drying of fuels. Extent & spread complicated by heterogeneity. In very dry climatic conditions, riparian corridors can act a route fire spread (wind tunnel effect). More often, riparian areas make a natural fire break. Riparian vegetation diversity & adaptations & access to water lead to faster recovery (Reeves *et al* 2006, Pettit & Naiman 2007).

h. Olson & Agee (2005) found historic fire return intervals of 4-167 years for riparian areas & 2-110 years for upland area in the mixed-severity fire regime of the Umpqua basin (not significantly different). Fire was patchy & riparian areas had a greater range of return intervals than upland slopes.
   i. Drier end of Douglas-fir/western hemlock distribution.

i. Windthrow is a common riparian disturbance type that contributes large wood to streams & creates patches of different ages. Windthrow rates are significantly higher on buffered clearcut streams compared to partial cuts or controls; however, it is a minor contributor to overall sediment loads (Rashin *et al* 2006). Loss of trees would reduce shade.

j. Conifers are uncommon in many unmanaged Coast Range riparian areas. Hardwood dominance due to competition & small-scale disturbance is common (Nierenberg & Hibbs 2000).
k. Temperature 303(d) listings & TMDLs exist across Oregon's landscape.
l. If only 2-6% of landscape were in recently harvested (≤10yrs since harvest) condition at the 6th field scale, then there are significantly reduced risks of water quality impacts & fisheries impacts (see Thompson *et al* 2006 for information on historical disturbance as a reference for forest policy/harvest).

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Water Quality Program

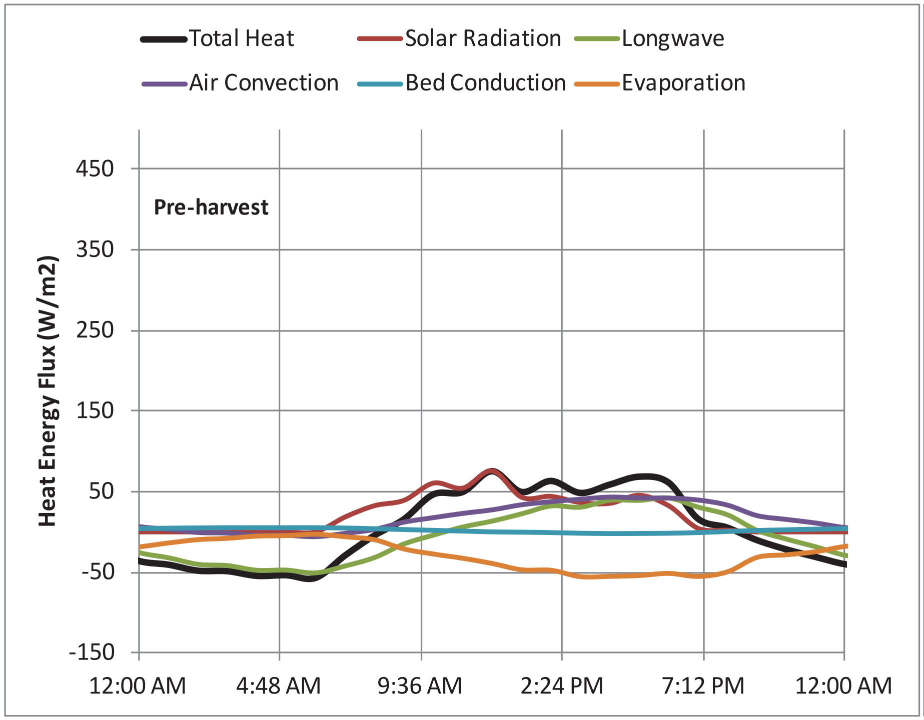
Figures for Oregon Forest Industry Council's Questions/Concerns

Re: Protecting Cold Water Criterion

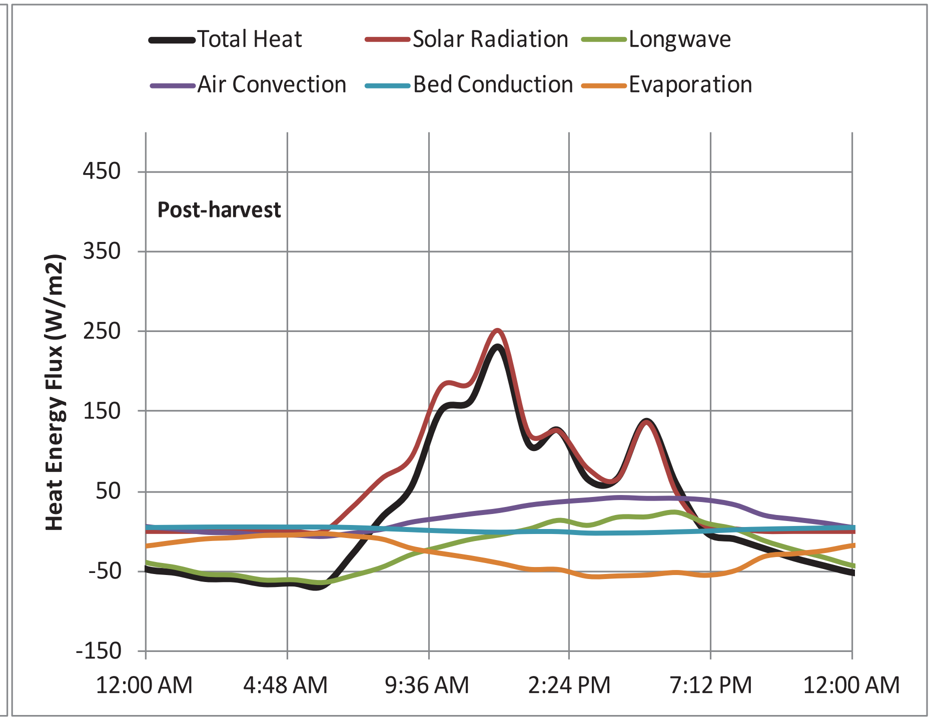
June 19th, 2014

State of Oregon Department of Environmental Quality

Figure 1: Energy Fluxes @ RipStream Site 5556

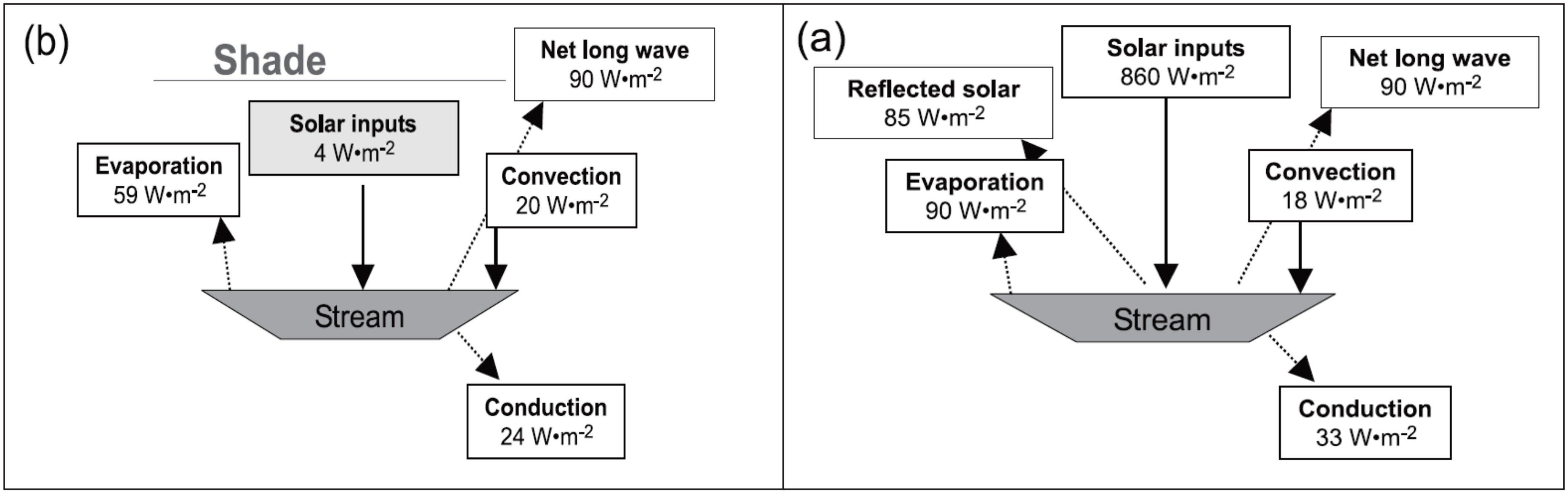


Modeled heat energy fluxes **<u>pre harvest</u>** at stream km 1.25 in the treatment reach on July 31, 2003.



Modeled heat energy fluxes **<u>post harvest</u>** at stream km 1.25 in the treatment reach on July 31, 2003.

Figure 2: Field Measured Energy Fluxes

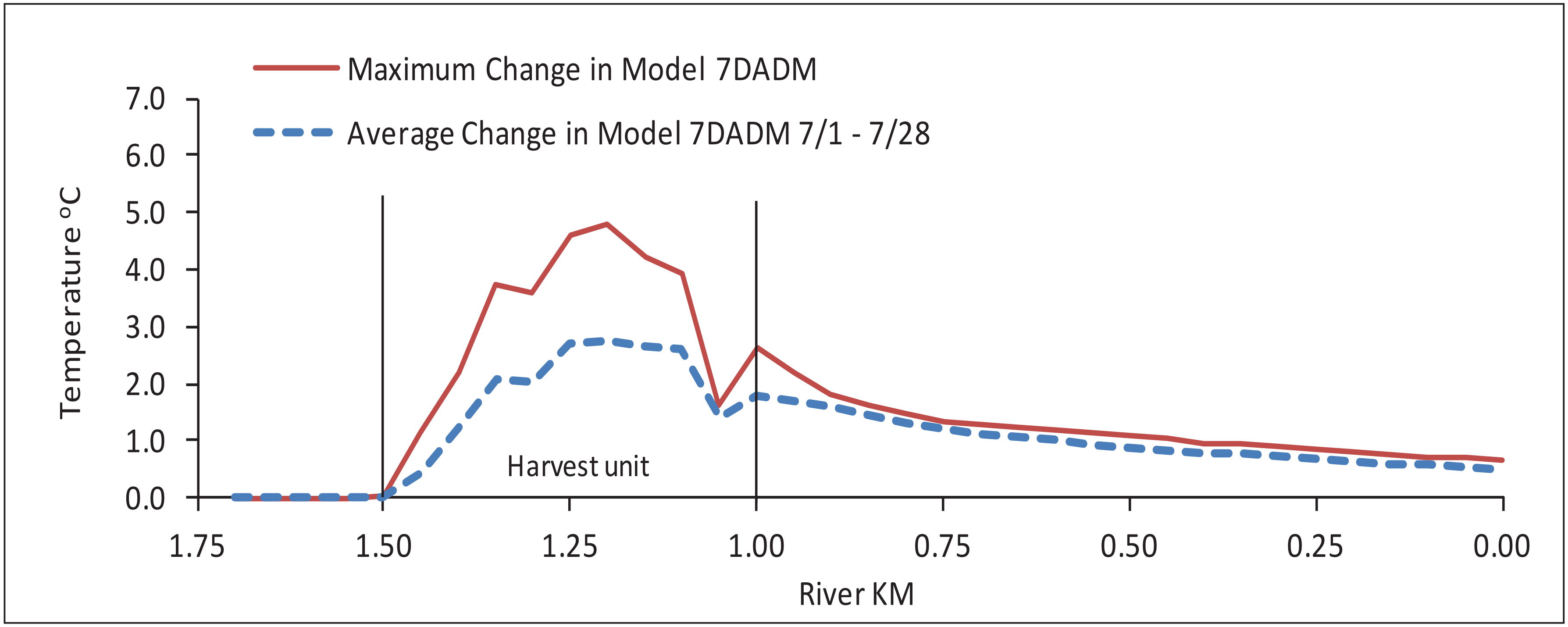


Thermal energy fluxes at noon on July 20, 1997 on a **fully shaded** study stream in the H.J. Andrews Experimental Forest. **Thermal energy lost is -149 W*m^{-2}.**

Thermal energy fluxes at noon on July 20, 1997 on an **unshaded** study stream in the H.J. Andrews Experimental Forest. **Thermal energy gained is 580 W*m^{-2}.**

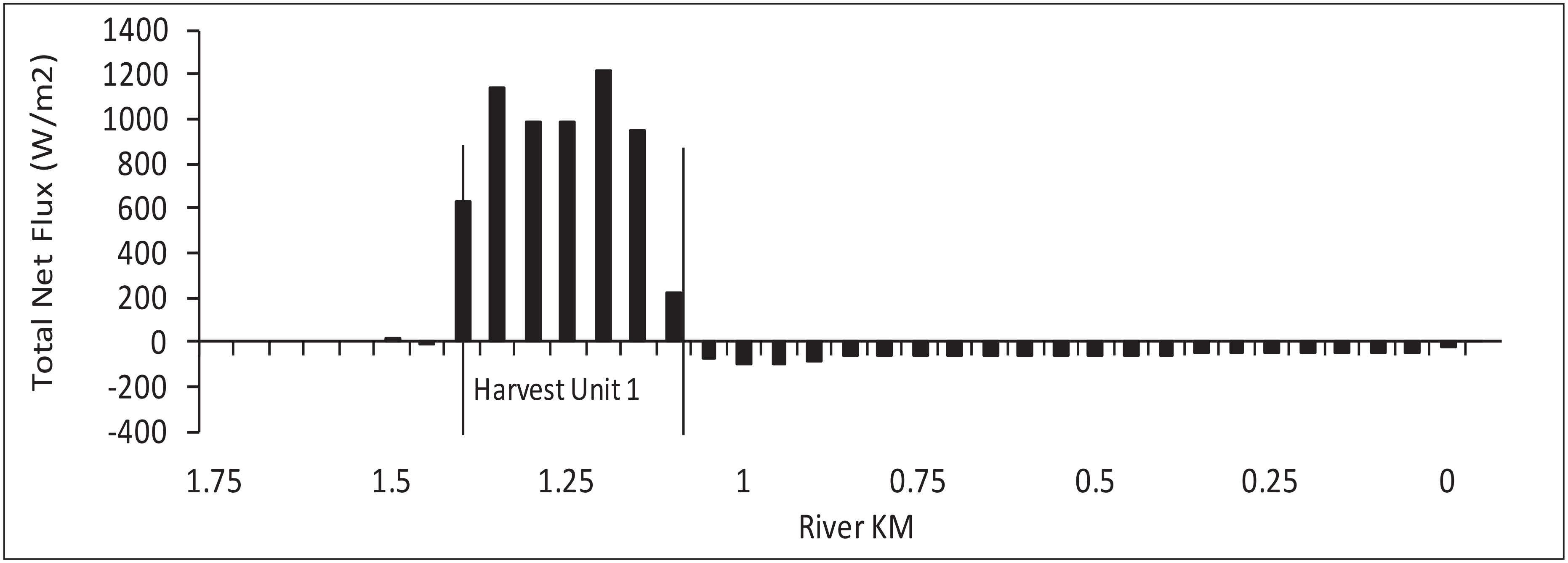
Johnson 2004

Figure 3: Heat Source Results for Argue Creek



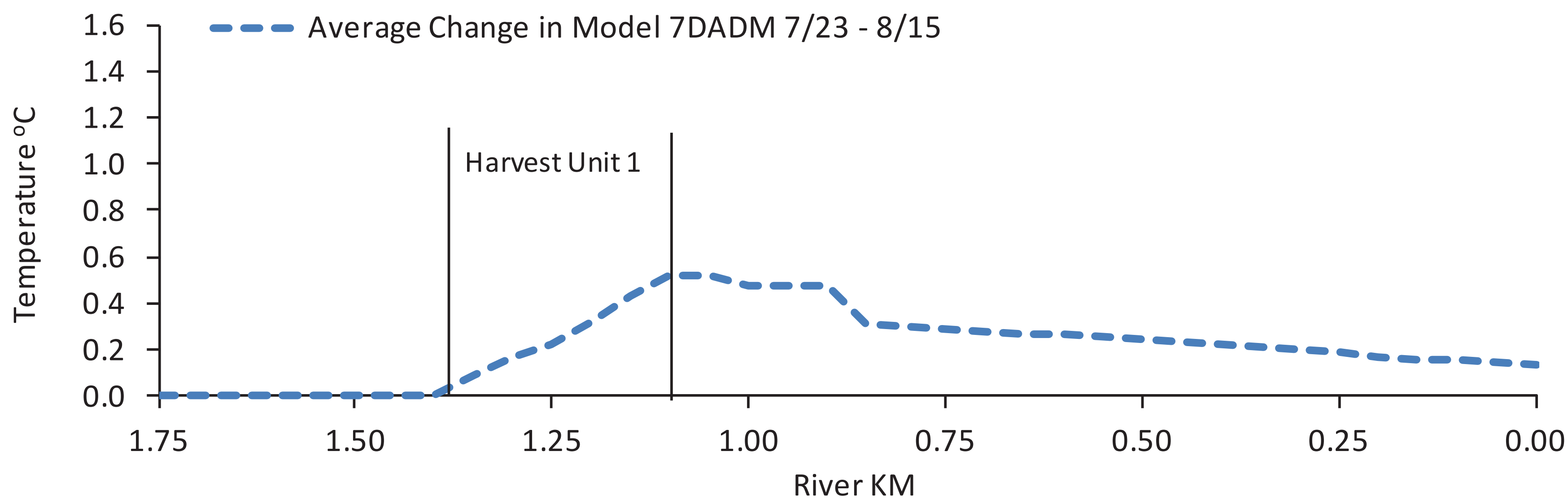
Simulated change in longitudinal 7-day average daily maximum (7DADM) temperatures from harvest at RipStream site 7854, holding all factors constant except vegetation.

Figure 4: Heat Source Results for Drift Creek Trib



Simulated change in longitudinal net energy fluxes from harvest at RipStream site 5556, holding all factors constant except vegetation.
Results only include effect of the Harvest Unit 1 in RipStream study area.

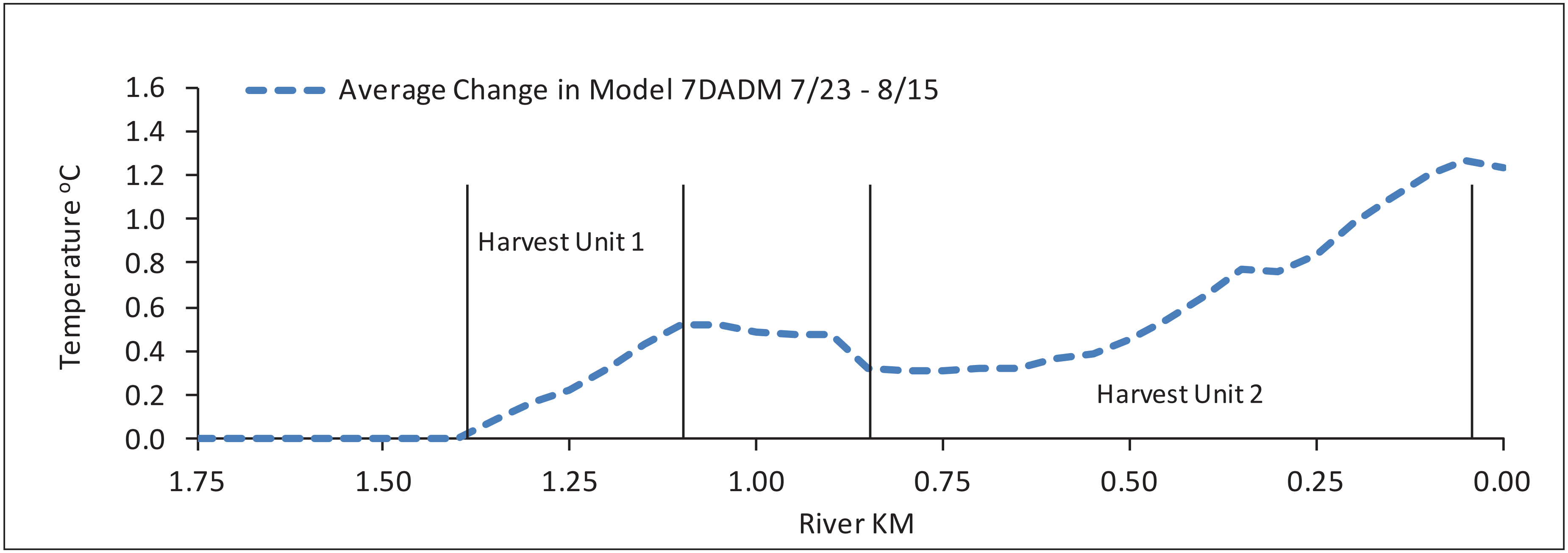
Figure 5: Heat Source Results for Drift Creek Trib



Simulated change in longitudinal 7-day average daily maximum (7DADM) temperatures from harvest at RipStream site 5556, holding all factors constant except vegetation.

Results only include effect of the Harvest Unit 1 in RipStream study area.

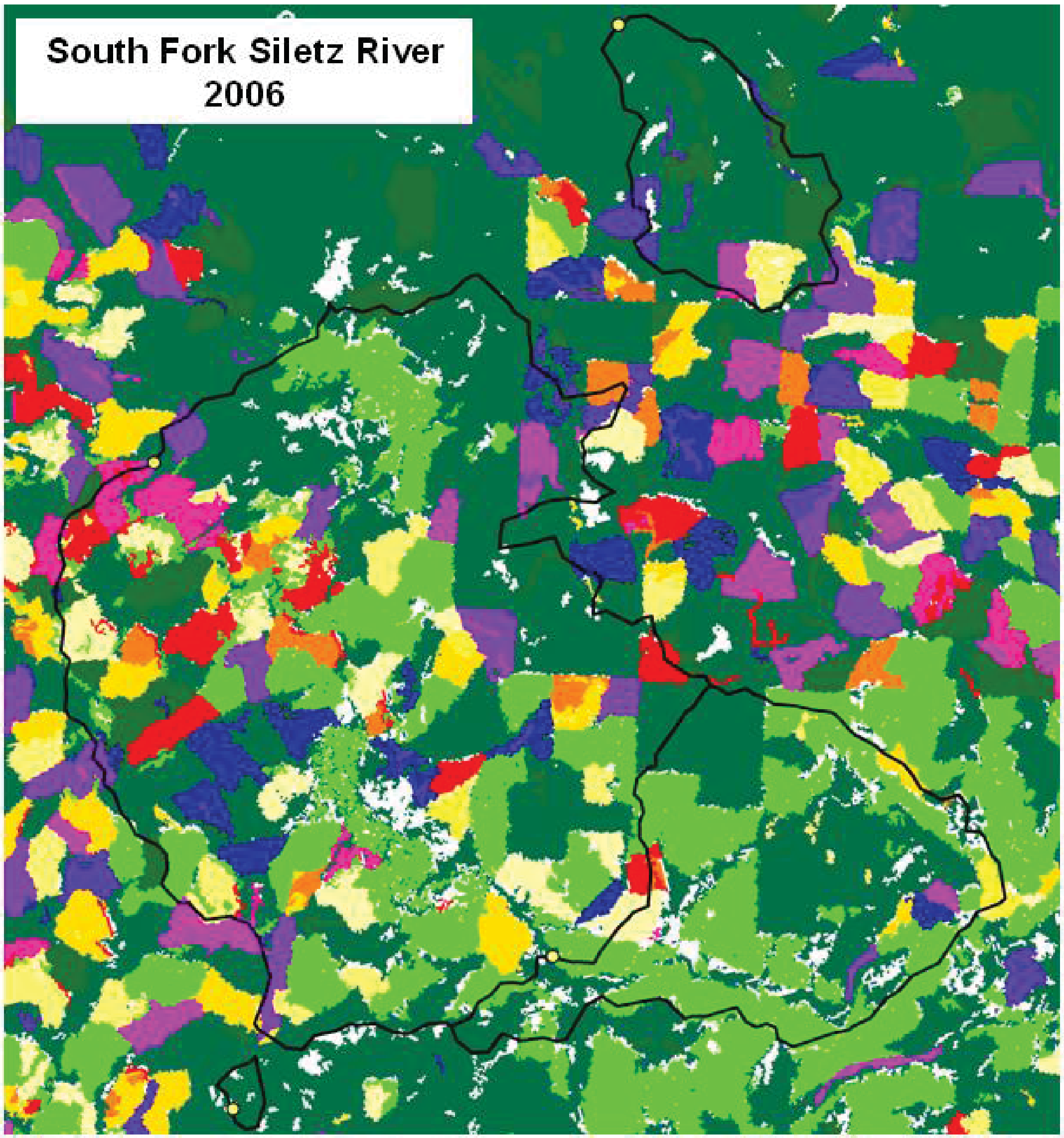
Figure 6: Heat Source Results for Drift Creek Trib

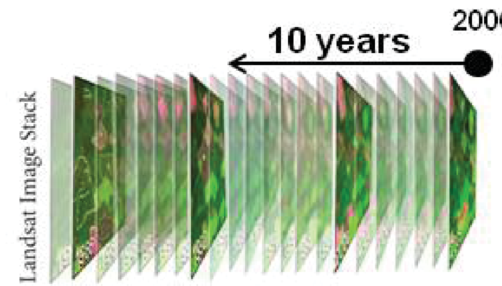


Simulated change in longitudinal 7-day average daily maximum (7DADM) temperatures from harvest at RipStream site 5556, holding all factors constant except vegetation.

Results include effects from the harvest unit in RipStream study area (Harvest Unit 1) and a second harvest unit downstream of the study area (Harvest Unit 2).

Figure 7: Change Detection Analysis





Kennedy et al 2010.

Percent area disturbed in 2006 = 17%

Includes any harvest 10 years prior from 1996-2006.

Color = harvested 1996 - 2006

White = Non forested (Ag/Rural residential, meadow)

Dark Green = not harvested 1985 - 2006.

Light Green = harvested 1985-1996. (Not counted in total)

Figure 8: Thermal Recovery in Middle Siletz River

Percent of riparian area in thermal recovery (≤10 years post-disturbance) **<u>as a percentage of the land use in question</u>**.

Percentages in the legend are the amount of the total watershed area in that land use.

Riparian areas are land within 100ft of streams.

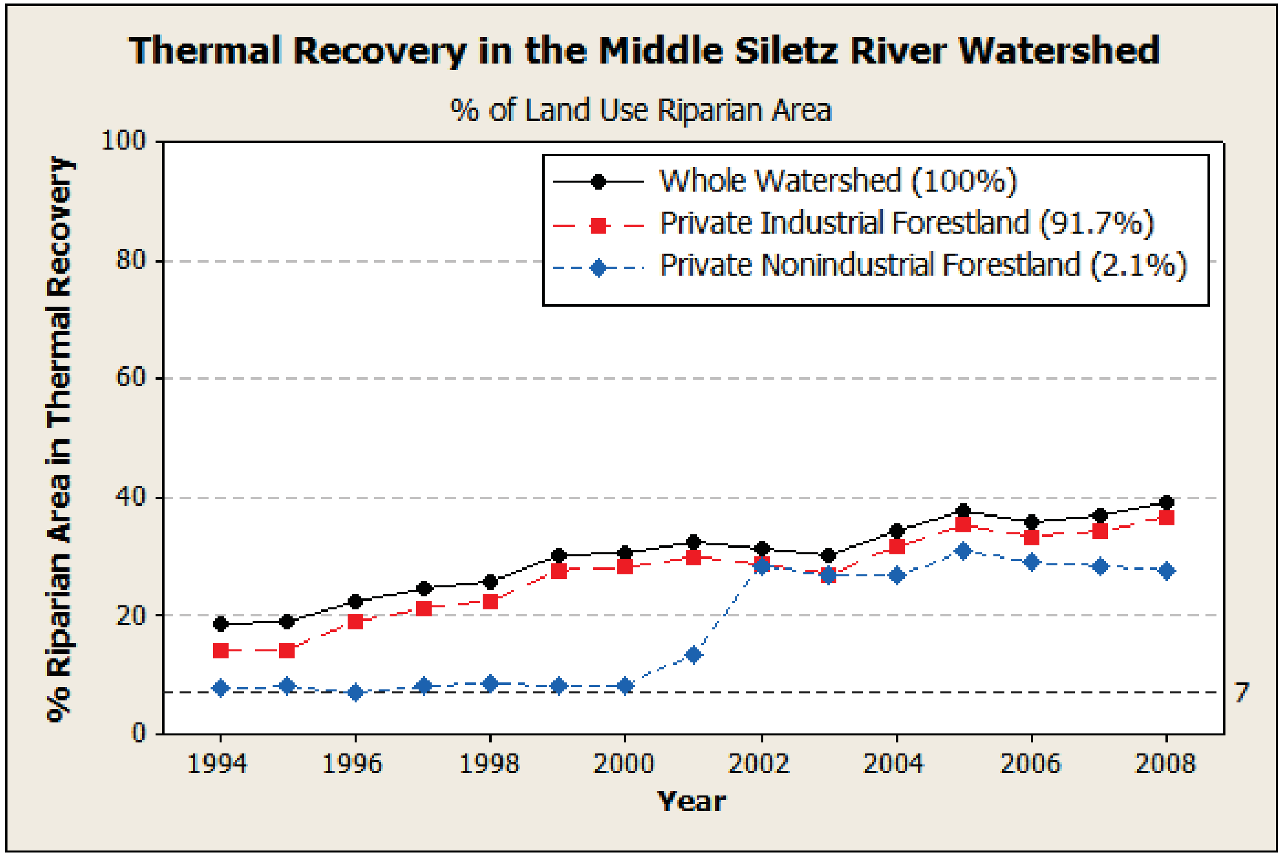


Figure 9: Thermal Recovery in Middle Siletz River

Percent of riparian area in thermal recovery (≤10 years post-disturbance) **as a percentage of the total watershed riparian area**.

Riparian areas are land within 100ft of streams.

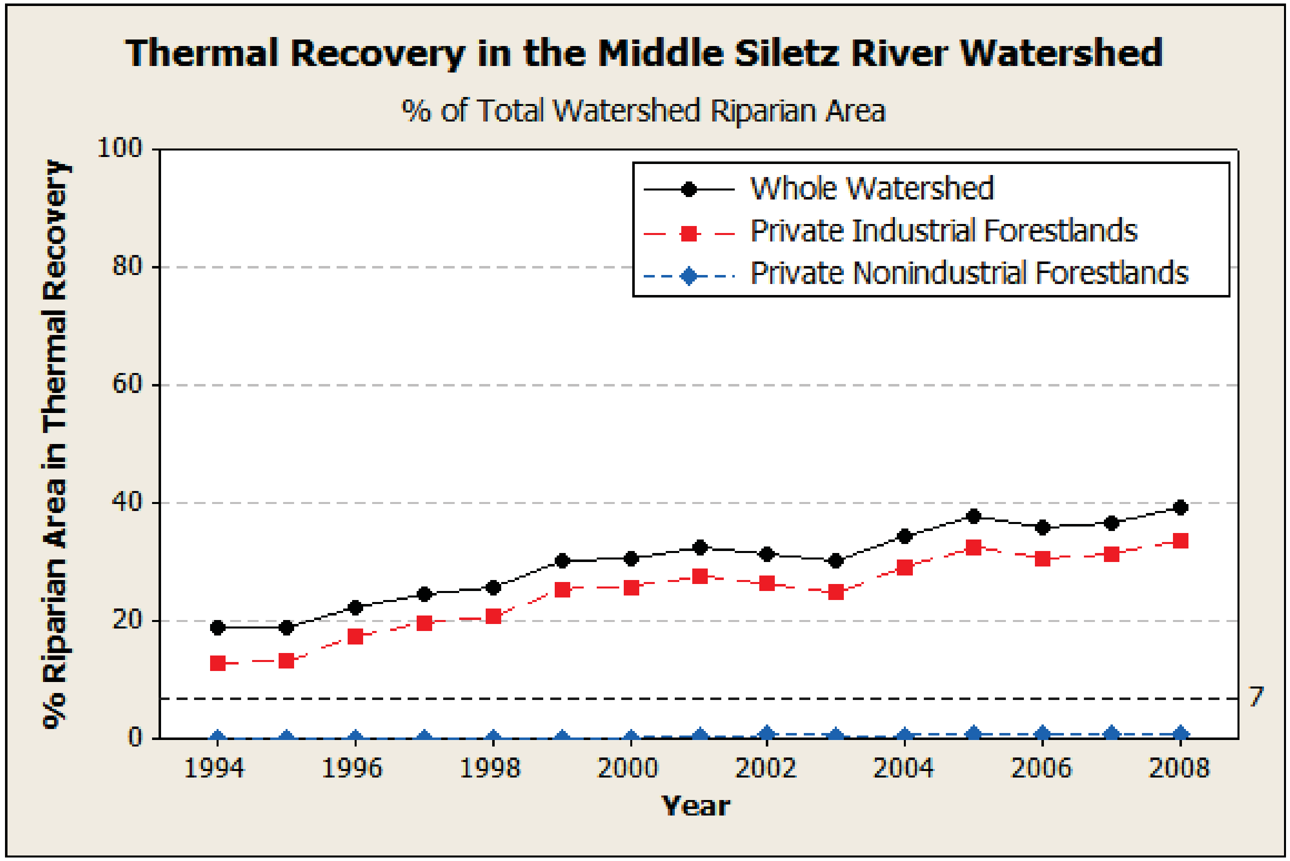


Figure 10: Thermal Recovery in Drift Creek

Percent of riparian area in thermal recovery (≤10 years post-disturbance) **<u>as a percentage of the land use in question</u>**.

Percentages in the legend are the amount of the total watershed area in that land use.

Riparian areas are land within 100ft of streams.

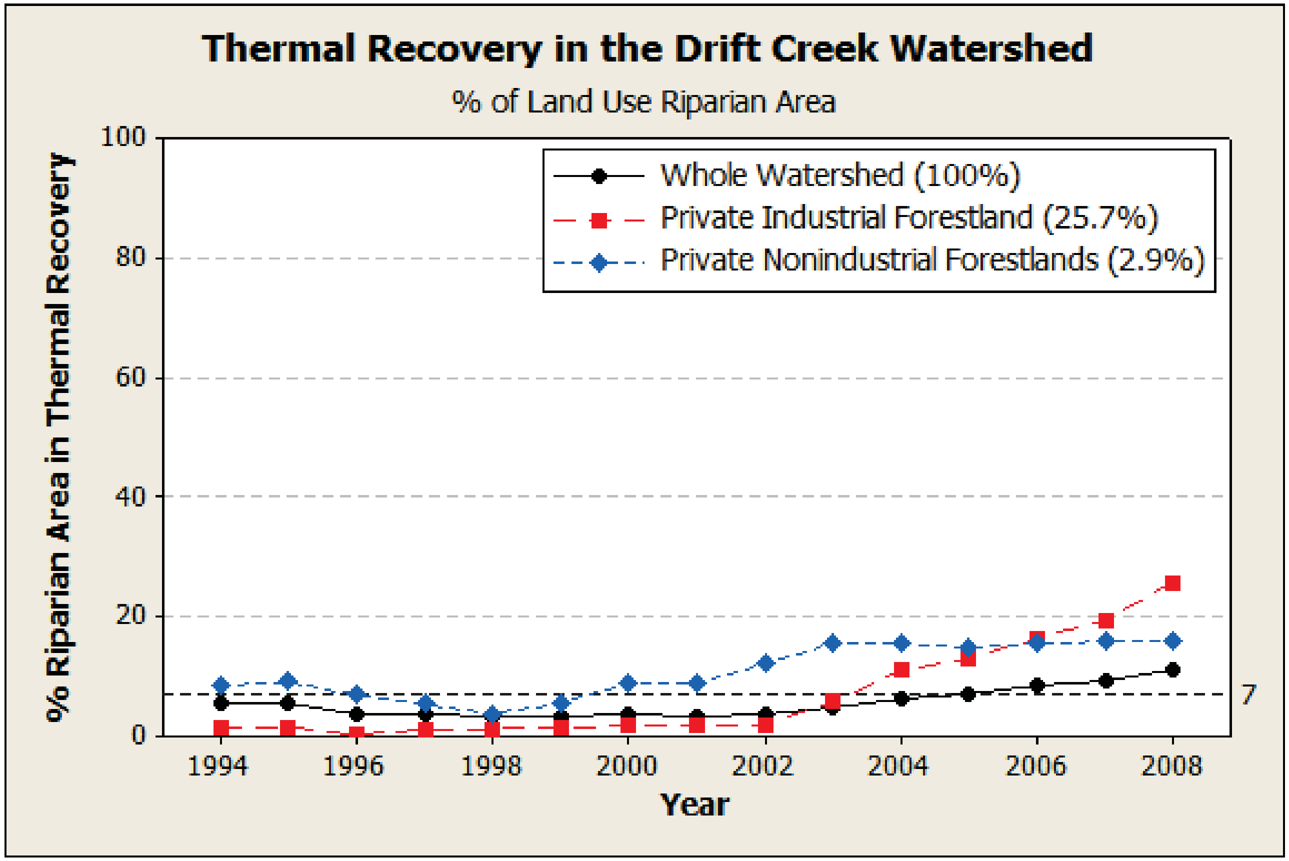


Figure 11: Thermal Recovery in Drift Creek

Percent of riparian area in thermal recovery (≤10 years post-disturbance) **as a percentage of the total watershed riparian area**.

Riparian areas are land within 100ft of streams.

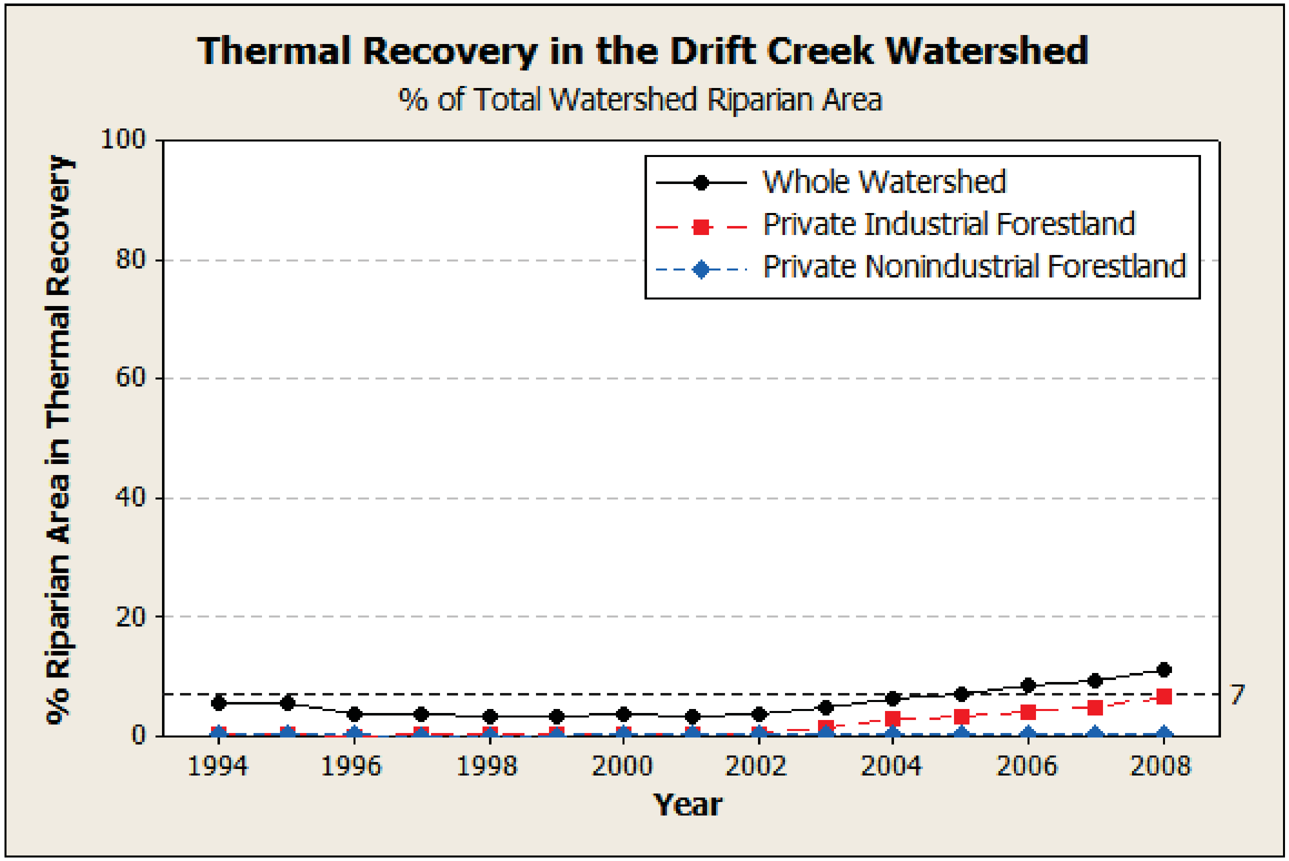
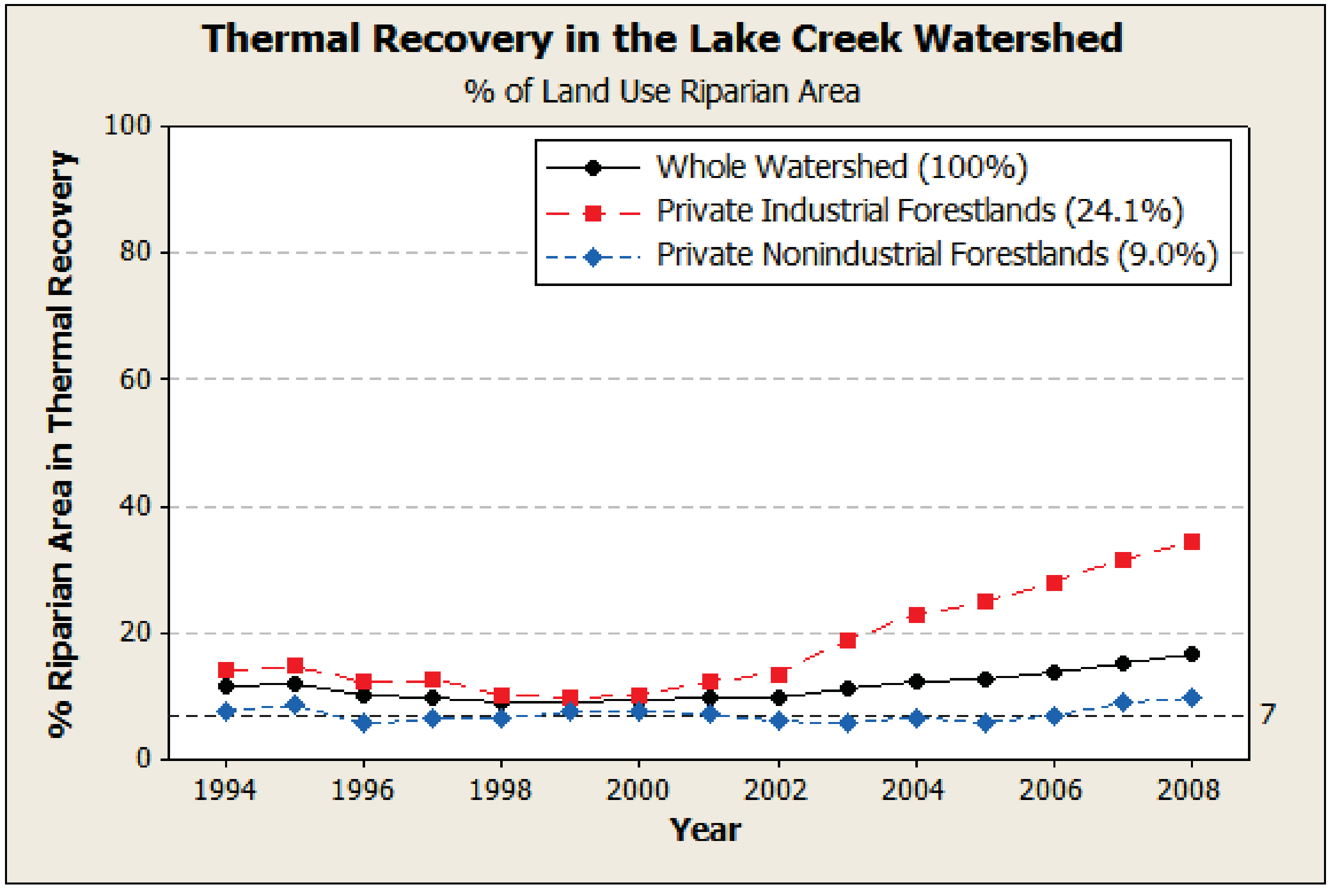


Figure 12: Thermal Recovery in Lake Creek

Percent of riparian area in thermal recovery (≤10 years post-disturbance) **as a percentage of the land use in question**.

Percentages in the legend are the amount of the total watershed area in that land use.

Riparian areas are land within 100ft of streams.

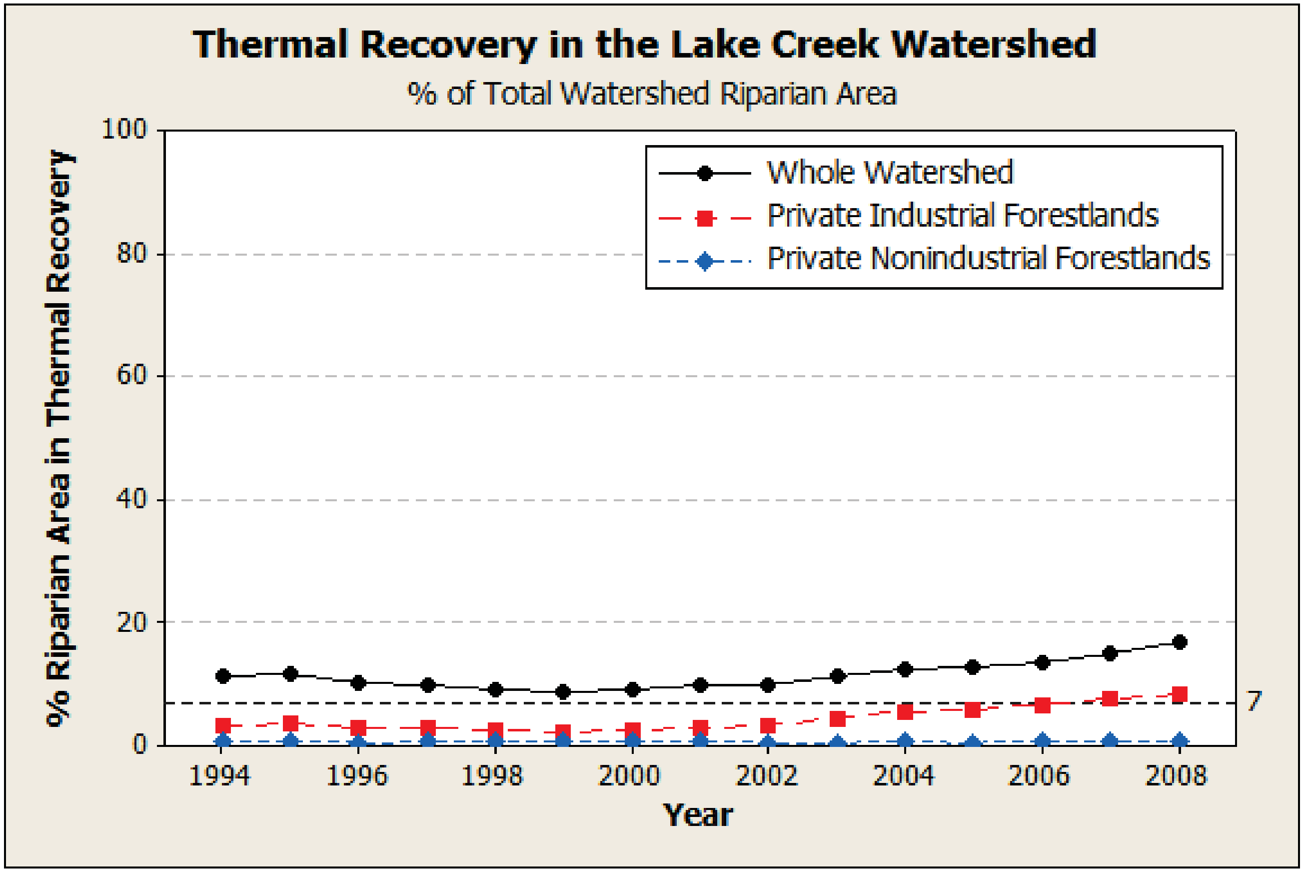


EPA-6822_000112

Figure 13: Thermal Recovery in Lake Creek

Percent of riparian area in thermal recovery (≤10 years post-disturbance) **<u>as a percentage of the total watershed riparian area</u>**.

Riparian areas are land within 100ft of streams.



Responses to Questions/Concerns Raised by Oregon Forest Industries Council Regarding the Protecting Cold Water Criterion of Oregon's Temperature Water Quality Standard

State of Oregon Department of Environmental Quality

Oregon Department of Environmental Quality
Oregon Department of Fish and Wildlife

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Date: 6/19/2014

Reasons for a Protecting Cold Water Criterion:

- A natural thermal regime provides best conditions for fish & other native aquatic organisms;*
- There is ecological value in a diversity of temperatures, including streams colder than BBNC, in part because thermal diversity promotes aquatic biological productivity;*
- Prevent accumulation of heat in fish-bearing reaches;*
- Retain assimilative capacity to buffer climate variation & climate change.

*From Summary of 2003 Technical Advisory Committee findings

Responses to Forest Industry Questions/Concerns:

1. Paired watershed studies add to the body of science on the association of new harvest treatments on stream temperature & short-term fish response, but not in a way that shows a lack of need for the Protecting Cold Water Criterion.
   a. Hinkle & Alsea studies show increases in fish-bearing streams within the range of responses from RipStream.
   b. Biological inference of WRC studies is correlative, short-term, and at the sub-catchment scale in lower order tributaries, and primarily within the distribution of resident cutthroat trout.
   c. The purpose of the standard is maintenance and restoration of natural thermal regimes across the landscape for all aquatic species.
   d. Prevention of short-term, reach level effects to fish are a goal to the standard, but are not the primary purpose.
   e. Meeting the standard preserves the capacity of waterbodies to assimilate natural fluctuations in temperature due to year-to-year climate variations & to better maintain cold-water communities in a warming climate (Bisson *et al* 2003, Mote 2003, INR 2009, Ruesch *et al* 2012).

2. Thermal diversity across the landscape is biologically necessary. Small increases in stream temperature can have negative effects on fish populations, particularly when occurring across the landscape.
    a. Temperature 303(d) listings & TMDLs exist across Oregon.
    b. Heating of headwaters reduces the extent of downstream waters at optimal growth & physiological temperatures & increases the extent at high-risk & lethal temperatures for rearing & migration.
    c. Temperature effects typically occur on a continuum; increases from natural thermal potential increase risk to fish (McCullough 1999, US EPA 2001).
    d. The natural thermal regime (NTR) is dynamic & variable, promoting biological diversity & resilience among fish populations & other native aquatic organisms (e.g. Watters *et al* 2003, Olden & Naiman 2010).
        i. Landscape alteration & climate change alter the mean & *<u>the variance</u>* of these temperature components (Steel *et al* 2012).
        ii. Timing of fish life history attributes (adult migration, spawning, fry emergence, smolt migration) is partially mediated by the NTR (Vannote & Sweeney 1980).
        iii. Homing to natal streams & natural selective forces (including those imposed by NTR) result in distinct, *<u>locally adapted</u>* populations (Hillborn *et al* 2003).
    e. Thermal diversity promotes aquatic biological productivity**.**
        i. Fish use thermal diversity (temporally & spatially) so impacts to the "pattern" of temperature can be as significant as changes to the mean or maximum temperature (see DEQ 2003).
        ii. Fish detect & exploit thermal heterogeneity to avoid heat stress & to meet metabolic & reproductive requirements (Berman & Quinn 1991, Hodgson & Quinn 1991, Ebersole *et al* 2003, Torgersen *et al* 2012).
        iii. Variation in thermal regimes directly influences:
            1. Metabolic rates, physiology, & life-history traits of aquatic ectotherms (see Holtby *et al* 1989 for salmonid example);
            2. Rates of important ecological processes such as nutrient cycling & productivity;
            3. Indirectly mediates biotic interactions (references in Olden & Naiman 2010).
    f. Heat accumulation (& other homogenizing effects) can alter thermal heterogeneity before "average" main channel temperatures change (Poole & Berman 2001).
    g. Multiple stressors in the environment must be considered. By preventing or reducing temperature stress, we reduce the risks due to multiple stressors on fish populations (e.g. OCCCP bottlenecks; e.g. Laetz *et al* 2014, Ray *et al* 2014).
    h. When there is uncertainty, DEQ must make conservative choices to ensure protection of the resource.

3. Thermal loads do move downstream, heat loss mechanisms are much less efficient than heat gain by solar radiation, & dilution of thermal loads is not the same as dissipation, especially with multiple harvests.
    a. In open canopy streams, input of solar radiation typically composes about 50% – 90% of the total heat energy flux (Figures 1 & 2; see Johnson 2004, Benyahya *et al* 2012).
    b. A single source's temperature effects become hard to track downstream, but DEQ calculates thermal loads for TMDLs & permits.
    c. DEQ HeatSource modeling indicates long distances (>1000 meters) are required to lose thermal energy via evaporation & longwave radiation (when tributary & groundwater inputs are held constant).
        i. HeatSource modeling on 2 RipStream sites (5556 & 7854) shows persistent temperature increases a kilometer or more from the end of harvest units (Figures 3, 4, & 5); and
        ii. Harvest of an additional downstream unit on 5556 creates greater increase at confluence with Drift Creek (Figure 6).
    d. Cole & Newton (2013) showed that with uncut units interspersed with harvest units, stream reaches showed overall increases in temperature trends post-harvest for 3 of 4 study reaches.

4. The current disturbance regime is very different than the pre-settlement disturbance regime in both frequency & type of disturbance.
    a. Thermal recovery post-disturbance is 7-15 years, with 10 years as a reasonable mid-range value (Johnson & Jones 2000; D'Souza *et al* 2011; Rex *et al* 2012; RipStream data, *unpublished*).
    b. With a 40-year rotation (assuming steady yearly harvest rate), 25% of the private industrial forestland base would be in thermal recovery.
    c. Based on change in Landsat land cover from 1985-2009 (Figure 7), the average percentage of private forestland (65.1% of total land area) in the MidCoast basin in the 10-yr thermal recovery period is 17% for the time period 1994-2009.
        i. The total for all land uses combined is 10%.
        ii. Varies over time & space.
            1. In 2008, 39.9% of private forestland in the Middle Siletz River watershed was in thermal recovery.
            2. In 1996, 5.3% of private forestland in the Drift Creek watershed was in thermal recovery. [Maximum of 34.9% in 2008]
    d. Based on change in Landsat land cover from 1985-2009, the average percentage of private forestland riparian areas in the MidCoast basin (43.8% of total riparian area (within 100ft of streams)) in the 10-yr thermal recovery period is 14.1% for the time period 1994-2009.
        i. The average for private industrial forestland is 15.6% (36.2% of total riparian area) & for private nonindustrial forestland is 10.2% (7.6% of total riparian area).

ii. The percentage of recently**+**chronically disturbed riparian areas is 20.7% for private forestlands during the same time period (20.4% & 21.8% for industrial & nonindustrial, respectively).

iii. The average recent disturbance for riparian areas of all land uses collectively is 8.7%. The average chronic disturbance for riparian areas of all land uses collectively is 14.0%.

iv. Varies over time & space.

1. In 2008, 36.7% of private industrial forestland riparian area in the Middle Siletz River watershed was in thermal recovery (maximum). The minimum of 14.1% occurred in 1994 (Figures 8 & 9).
2. In 1996, 0.2% of private industrial forestland riparian area in the Drift Creek watershed was in thermal recovery (minimum). The maximum of 25.8% occurred in 2008 (Figures 10 & 11).
3. In 1999, 9.7% of private industrial forestland riparian area in the Lake Creek watershed was in thermal recovery (minimum). The maximum of 34.5% occurred in 2008 (Figures 12 & 13).

e. Agee (1990) estimates that historically (prior to Euro-American settlement) an average 0.24% and 0.67% of cedar/spruce/hemlock and western hemlock/Douglas-fir forests, respectively, burned annually.

i. Gives an average area in thermal recovery estimate of 2.4% for cedar/spruce/hemlock & 6.7% for western hemlock/Douglas-fir.

f. Wimberly (2002) estimates that a median of 17% of Oregon's coastal province would be in early successional condition (<30 years since fire of varying severity).

i. Using 10 years as above, Wimberly's estimate gives 5.7% of forestlands historically in thermal recovery.

g. High-severity fires leave more wood & live vegetation than clearcut harvest, and there are differences between unmanaged terrestrial & riparian early succession compared to clearcut harvest & replanting methods (Reeves *et al* 1995, Reeves *et al* 2006, Swanson *et al* 2011).

h. Fire return intervals in western Oregon range from 100-400 years. Shorter intervals typically are associated with less severity (Morrison & Swanson 1990).

i. Fire return for high severity fires is typically 200 years (Wimberly 2002), compared to harvest rotation of 40 years.

j. Periodic large scale disturbances create a mosaic of riparian & aquatic habitats (Bisson *et al* 2003). Pulses of sediment & large wood are delivered by post-fire erosion, in contrast to chronic inputs.

i. It is important to conserve & restore processes by managing for natural disturbances or like natural disturbances, not merely by creating structures or conditions.

k. Generally, riparian areas along streams higher in watersheds tend to burn along with upland forests, while riparian areas lower in watersheds are less likely to burn & more prone to flood disturbance (Reeves *et al* 2006, Pettit & Naiman 2007).

i. Fire can be less common in riparian areas due to higher moisture content & humidity.
ii. Some studies (e.g. Tollefson *et al* 2004, Olson & Agee 2005) have found no difference between upland & riparian fire frequency, particularly when riparian vegetation is similar to upland vegetation.
iii. Riparian areas often have higher fuel loads (higher productivity) & in prolonged drought can become more fire-prone.
iv. Riparian fires tend to be very patchy, primarily burning fine fuels. Conditions retard fuel drying & decrease severity. Extent & spread are complicated by ecosystem heterogeneity.
v. In very dry climatic conditions, riparian corridors can act as a route for fire to spread (wind tunnel effect). More often, riparian areas act as a natural fire break.
vi. Harvesting increases fuel loads & opens up the canopy, allowing faster drying of fuels.
vii. Riparian vegetation diversity & adaptations along with better access to water lead to faster recovery.

5. If taking a non-conservative approach to the effects of a single harvest, then we must address actual landscape conditions & the effects of multiple harvests.

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